Fisheries and Oceans Canada / Pêches et Océans Canada

Science / Sciences

Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/048

UPDATE TO THE RECOVERY POTENTIAL FOR CUSK IN CANADIAN WATERS

Photo: DFO

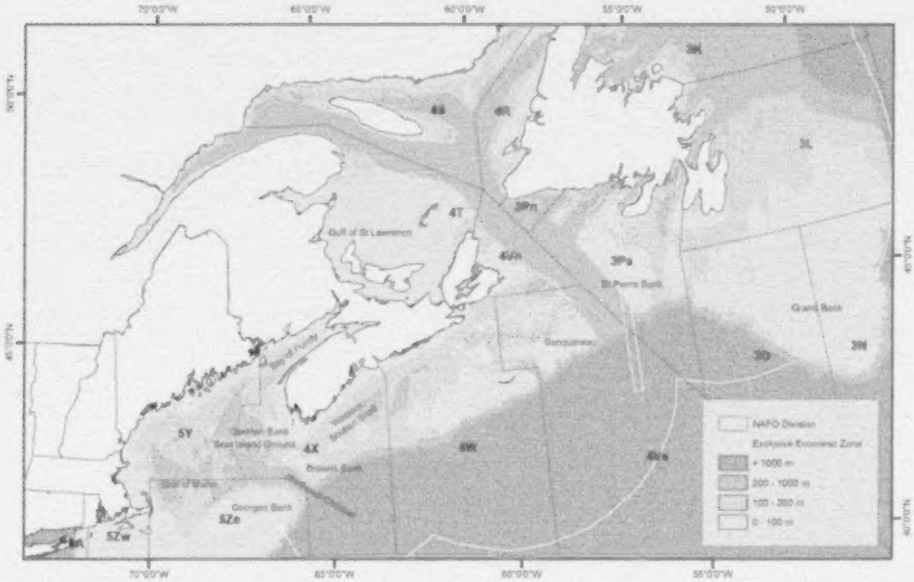

Figure 1. NAFO Divisions, Exclusive Economic Zone boundary, and oceanographic features on the Scotian Shelf and Grand Bank.

Context:

Cusk (Brosme brosme) was assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2003. In 2013, the Governor in Council, on the recommendation of the Minister of the Environment, decided not to add Cusk to the List of Wildlife Species at Risk set out in Schedule 1 of Species at Risk Act (SARA). Meanwhile, Cusk was reassessed as Endangered by COSEWIC in November 2012. The reasons for designation are, "This species is a large, slow-growing, bottom-living fish that resides in the Gulf of Maine and Scotian Shelf, and which has been declining continuously since 1970. The mature portion of the population has declined by approximately 85% over three generations. There is also strong evidence that its area of occupancy has declined considerably. Average fish size has also declined, consistent with a decline in abundance. Limited management efforts have not been effective in halting the decline." (COSEWIC 2012). A Recovery Potential Assessment (RPA) for Cusk was completed in 2007 (DFO 2008) following the first assessment of the species by COSEWIC in 2003. DFO Science has been asked to update the RPA, based on the National Frameworks (DFO 2007a and b). The advice generated via this process will update and/or consolidate

Canada

previous advice and support a new listing recommendation for Cusk. The advice in the update may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA.

This Science Advisory Report is from the February 12-13, 2014, Update on Recovery Potential for Cusk (Brosme brosme). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Cusk (*Brosme brosme*) was assessed as Threatened by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2003. In 2013, the Governor in Council decided not to add Cusk to the List of Wildlife Species at Risk set out in Schedule 1 *Species at Risk Act (*SARA). Cusk was reassessed as Endangered by COSEWIC in November 2012 for reasons that include long-term declines beginning in the 1970s.
- Commercial catch rates for Cusk have declined since the 1980s. The extent of the decline in abundance cannot be reliably estimated. The Halibut Industry Survey, which began after the decline in commercial catch per unit effort (CPUE) was observed, has fluctuated without trend since 1999. This suggests that the population abundance has stabilized.
- The reference points for Cusk under the DFO Precautionary Framework were set at an Upper Stock Reference (USR) of 26.6 kg/1000 hooks and a Limit Reference Point (LRP) of 13.3 kg/1000 hooks in the Halibut Industry Survey. The 3-year geometric mean (2011-2013) of the Cusk CPUE is 17.9 kg/1000 hooks, which suggests that the stock is in the cautious zone. The Upper Stock Reference Point of 26.6 kg/1000 hooks in the Halibut Industry Survey is the proposed population recovery target.
- There is no evidence of a reduction in the range of Cusk. The proposed distribution target for recovery is to maintain current distribution.
- Fishing is the only known major source of human-induced mortality of Cusk in Atlantic Canada. Groundfish longline and lobster pots are considered the greatest threats based on landings records and discard estimates, respectively.
- The most recent landings estimates for a full fishing year are from 2012. The Cusk reported landings for the 2012 fishing year in Maritimes Region were 462.2 mt (Table 1). The 2012 Cusk landings for the Gulf Region and Newfoundland and Labrador Region were 0.043 mt and 1.88 mt, respectively.
- The Cusk bycatch for 2012 in Lobster Fishing Area (LFA) 41 was estimated at 8.6 mt. The 2006/2007 estimate of bycatch in LFA 34 was 344 mt. Cusk catches in other LFAs have not been evaluated.
- It appears that the population can sustain recent levels of fishing mortality without jeopardizing survival of the species considering Cusk CPUE in the Halibut Industry Survey has fluctuated without trend for the past 14 years. A further reduction in fishing mortality may be required for the species to achieve the proposed recovery target for abundance. It is not known if there are limiting factors (e.g. high natural mortality) that will prevent Cusk from recovering. Habitat does not appear to be, nor is likely to become, a limiting factor to Cusk survival and recovery. There are no known anthropogenic threats that have reduced Cusk habitat quantity or quality.

- Cusk have a fairly generalized diet. DFO data from Canadian waters indicate that crustaceans, primarily decapods comprised of various crab species and krill species; various fish species, including Silver Hake, Atlantic Herring, American Plaice and Atlantic Argentine; and molluscs, primarily Short-Fin Squid, are the main components of Cusk diet.
- Preliminary analyses suggest the six most influential environmental variables on Cusk habitat suitability, ranked using the Random Forest Model (Figure 6), were salinity variability, winter total suspended matter 2006-2010, fall benthic temperature, depth, root mean square (RMS) current stress, and winter benthic temperature. These variables are expected to have both indirect and direct relationships on Cusk distribution patterns.
- Cusk are most common on hard, rocky bottom or gravel and have been observed hiding in crevices. The benthic complexity index was not in the top ten predictors in the model, perhaps reflecting insufficient data on benthic complexity.
- Possible mitigation measures to decrease fishing mortality include: mandatory release; area closures for the groundfish longline and lobster fisheries; implementation of an avoidance protocol; and identification and implementation of best-handling practices to maximize post-release survival.

BACKGROUND

Rationale for Assessment

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designates aquatic species as Threatened or Endangered, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the *Species at Risk Act* (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population or designable unit (DU), threats to its survival and recovery, and the species' potential for recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes, including the decision whether or not to list a species on Schedule 1 and during recovery planning if the species is listed.

Cusk (*Brosme brosme*) was assessed as Threatened by COSEWIC in 2003. In 2013, the Governor in Council decided not to add Cusk to the List of Wildlife Species at Risk set out in Schedule 1 SARA. Cusk was reassessed as Endangered by COSEWIC in November 2012 for reasons that include long-term declines beginning in the 1970s. The reasons for designation given in the 2012 reassessment are, "This species is a large, slow-growing, bottom-living fish that resides in the Gulf of Maine and Scotian Shelf, and which has been declining continuously since 1970. The mature portion of the population has declined by approximately 85% over three generations. There is also strong evidence that its area of occupancy has declined considerably. Average fish size has also declined, consistent with a decline in abundance. Limited management efforts have not been effective in halting the decline." (COSEWIC 2012).

An RPA was completed for Cusk in 2007 (DFO 2008) following the first assessment of the species by COSEWIC in 2003. DFO Science has been asked to update the RPA, based on the National Frameworks (DFO 2007a and b). The advice generated via this process will update and/or consolidate previous advice regarding Cusk and support a new listing recommendation for Cusk. The advice in the update may be used to inform both scientific and socio-economic elements of the listing decision, and, if the species is listed under SARA, the development of a recovery strategy and action plan, as well as to support decision-making with regards to the

issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA.

Distribution and Biology

Cusk is a solitary, sedentary, slow-swimming species found across the northern North Atlantic from the United States, north to Greenland, across to Iceland, Svalbard, along the Murmansk Coast, and south in the Northeast Atlantic to Ireland. It has also been found along the mid-Atlantic Ridge. In Canadian waters, Cusk is most common in the Gulf of Maine, Western Scotian Shelf, and along the edge of the Scotian Shelf to Banquereau Bank (Figure 1 for locations of oceanographic features, Figure 2), although it has been caught from Cape Cod, in the United States, to Labrador. It is rare in the Gulf of St. Lawrence and the inner Bay of Fundy.

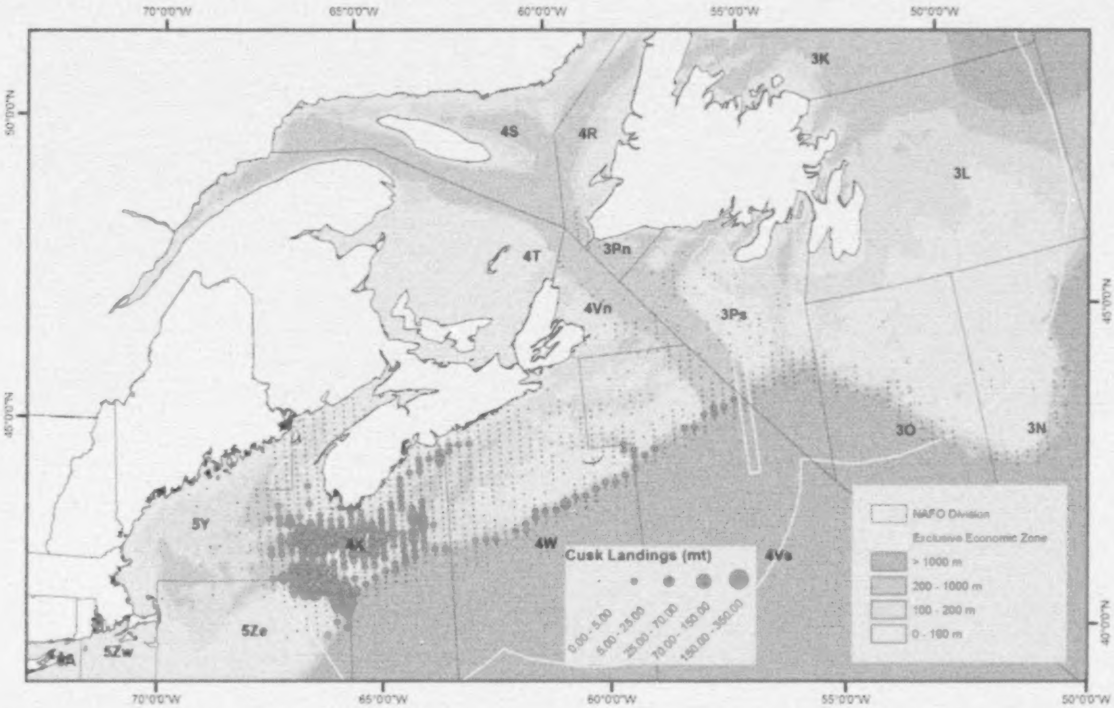

Figure 2. Magnitude and distribution of Cusk landings between 2002 and 2013 overlaid on NAFO and Exclusive Economic Zone boundaries. Landings data are summed, aggregated by 12 km grid cells. Landings without latitude and longitude are not represented, nor are landings that were reported to be on land or at a depth greater than 2000 m; a total of 95.91mt (1.27%) are not represented in this figure. Discarded fish are not shown.

There is no evidence of spatially separated populations of Cusk; rather, they seem to have a continuous distribution from the Gulf of Maine to the Grand Banks. Little is known of their life history, and no studies have been undertaken to compare the life history of Cusk caught in different areas of Canada. A study of Cusk mitochondrial DNA from samples collected in Canada, Greenland, Norway, and the Mid-Atlantic Ridge revealed no obvious geographic patterns in the distribution of mitochondrial diversity, and weak or no genetic structure was detected. Haplotypes were shared amongst regions and the most common haplotypes for the 3 loci studied were found in Canada, Norway, and Greenland. The larval data from the Scotian Shelf Ichthyoplankton Program (SSIP), which ran from 1976 to 1982, indicate one continuous spawning period from May to July or August, thus, do not suggest recruitment pulses of multiple spawning components.

The SSIP ichthyoplankton data and maturity studies indicate that spawning on the Scotian Shelf occurs from May to August and peaks in June, though port samplers have observed Cusk in spawning condition as early as March. Cusk are considered to be quite fecund, with reports of 100,000 to 3,927,000 eggs from 56 cm and 90 cm fish, respectively. It is not known how this translates to recruitment. Eggs are buoyant. Pelagic larvae are about 4 mm in length when hatched. Larvae migrate to the bottom when they reach approximately 50 mm in length.

Recently, radiocarbon bomb dating methods have been used to estimate the age of Cusk from Canadian waters. This ageing effort has returned older age estimates, including an 82 cm fish aged at 39 years, than studies conducted in the 1960s. These new ageing data also suggest that Cusk may reach maturity at 10 years in contrast to previous estimates of 5-6 years. These results are consistent with studies in the Northeast Atlantic, where maturity is attained at 8 to 10 years of age. Ageing Cusk from sectioned otoliths has proven to be difficult. Current efforts are yielding results consistent with the bomb radiocarbon dated otoliths. However, there is still further ageing and testing to be conducted before there is enough confidence in the ageing method to develop a growth curve.

The largest Cusk recorded in Canadian waters were caught in the Halibut Industry Survey (largest specimen measured 118 cm). Fish less than 40 cm were recorded infrequently by at-sea observers on industry surveys and commercial trips; there are only 48 specimens less than 40 cm of 3253 specimens measured. Juveniles 15 cm and less have been caught in annual DFO bottom trawl surveys, though infrequently; the species identification of these small fish is questioned but cannot be verified. If nursery areas exist for juvenile Cusk, they have not yet been observed.

ASSESSMENT

Status and Trends

There is no reliable abundance estimate for Cusk.

Commercial catch rates for Cusk have declined since the 1980s. Management measures (e.g., trip limits, overall caps, and bycatch percentages) may have contributed to this reduction in catch rates (and landings); however, it is thought the decline in catch per unit effort (CPUE) is also due to a decline in Cusk abundance (Harris and Hanke 2010). The extent of the decline in abundance cannot be reliably estimated. The Halibut Industry Survey, which began after the decline in commercial CPUE was observed, has fluctuated without trend since 1999. This suggests that the population abundance has stabilized.

In the absence of better information, the average of the commercial longline CPUE from the period of higher catch rates (1986-1992) in the commercial fishery was used as a proxy for biomass at Maximum Sustainable Yield. The reference points for Cusk under the DFO Precautionary Framework were set at an Upper Stock Reference (USR) of 26.6 kg/1000 hooks and a Limit Reference Point (LRP) of 13.3 kg/1000 hooks in the Halibut Industry Survey (Figure 3, Harris et al. 2012), 80% and 40%, respectively, of the average commercial CPUE from the 1986-1992 period. The 3-year geometric mean was accepted as the metric for monitoring Cusk status relative to the USR and LRP (Harris et al. 2012). The mean Cusk CPUE from the Halibut Industry Survey has been at or above LRP for the last 7 years. The 3-year geometric mean (2011-2013) of the Cusk CPUE is 17.9 kg/1000 hooks, which suggests that the stock is in the cautious zone. A high level of uncertainty is indicated by the wide confidence interval (Figure 3, DFO 2014a). The Upper Stock Reference Point of 26.6 kg/1000 hooks in the Halibut Industry Survey is the proposed population recovery target.

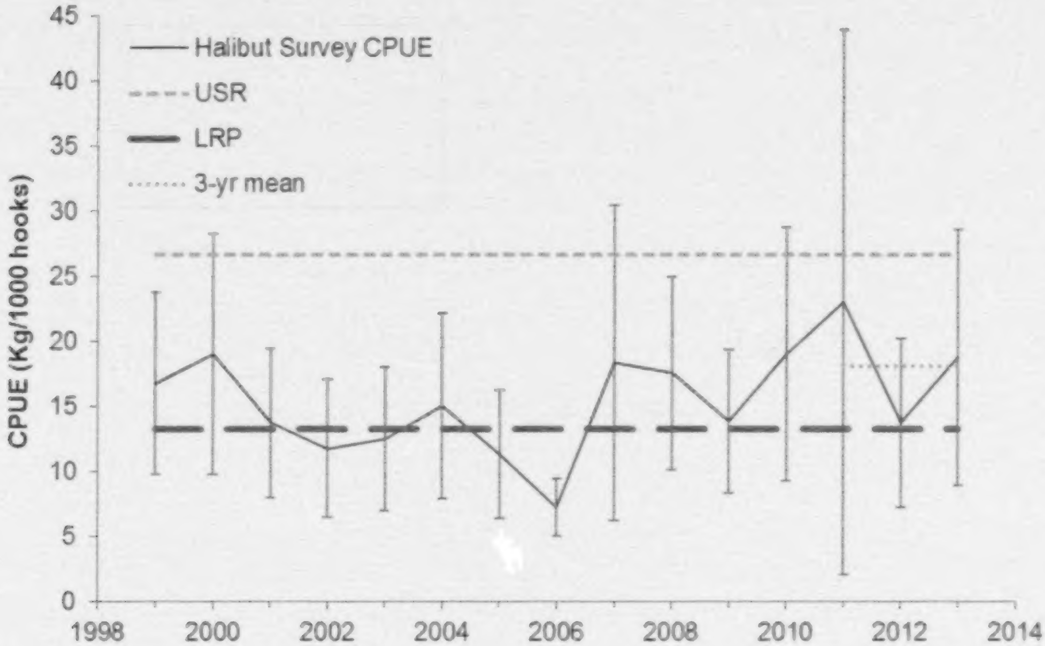

Figure 3. Abundance trends of Cusk in the Halibut Industry Survey. The green dashed reference line represents the Upper Stock Reference point (80% of the proxy for biomass at MSY), the red dashed reference line represents the Limit Reference Point (40% of the proxy for biomass at MSY), the solid black line represents the Halibut Industry Survey CPUE (kg/1000 hooks) including the 95% confidence interval, and the dotted blue line represents the geometric mean of the CPUE for 2011-2013.

Range

There is no evidence of a reduction in the range of Cusk. Anecdotal information suggests that localized depletions have occurred when 'Cusk holes' have been fished out. These areas are recolonized after several years with no fishing effort. Despite these short-term localized depletions, Cusk are still caught throughout their range from the Gulf of Maine, on the Scotian Shelf and Slope, to the Newfoundland-Labrador Shelf in both commercial fisheries and research surveys. The proposed distribution target for recovery is to maintain current distribution.

Threats

Fishing is the only known major source of human-induced mortality on Cusk in Atlantic Canada. Overfishing is identified as the most important threat to Cusk in the 2012 COSEWIC status report, specifically the Atlantic Cod, Haddock, Pollock and Atlantic Halibut fisheries (primarily bottom longline). Annual Cusk landings from Maritimes, Newfoundland and Labrador (NL), and Gulf regions have ranged from minimum landings of 317.3, 1.1, and 0.0 mt to maximum landings of 817.5, 7.6, and 0.5 mt, respectively, between 2002 and 2012 (Table 1). The majority of landings are from the groundfish longline fleet, accounting for over 95% in the Maritimes Region and over 90% in NL and Gulf regions from 2002 to 2012. In an average year, 73% of reported landings are from Northwest Atlantic Fisheries Organization (NAFO) area 4X, and 19% from NAFO Subarea 5 for the 2002-2013 period.

Table 1. Cusk landings in metric tons by fishing year, and gear type from 2002 to 2013. Data are from MARFIS (Maritimes), and Commercial Data Division (NL), and ZIF (Gulf).

Fishing Year	Gillnet	Bottom Longline	Bottom Trawl	Misc.**	Total
2002	13.2	1228.4	38.5	3.2	1283.3
2003	12.9	1023.4	30.10	3.5	1069.9
2004	6.5	781.4	35.9	0.6	824.3
2005	6.0	774.7	27.3	1.1	809.1
2006	5.1	768.0	23.5	3.3	799.9
2007	6.2	934.8	19.2	0.5	960.7
2008	5.2	541.0	19.8	0.3	566.3
2009	5.8	514.4	29.2	0.1	549.4
2010	15.2	410.0	21.7	0.2	447.1
2011	9.9	416.9	22.4	0.1	449.3
2012	9.9	435.7	18.5	0.1	464.1
2013*	9.2	205.2	9.00	0.0	223.5

*Denotes incomplete data for that Fishing Year
**Gear types qualified as "Misc." include midwater trawls, Scottish seine, and handline method

The most recent landings estimates for a full fishing year are from 2012. The Cusk reported landings for the 2012 fishing year in Maritimes Region were 462.2 mt (Table 1). The 2012 Cusk landings for the Gulf Region and NL Region were 0.043 mt and 1.88 mt, respectively.

Cusk caught in other fisheries, such as lobster and crab trap fisheries, must be discarded. In some Lobster Fishing areas (LFAs), effort is very low (e.g. LFA 41), thus the impact of lobster fishing in this area on Cusk is low relative to other LFAs. In some areas, Cusk are rare or absent (e.g. inshore NL), so lobster fishing is unlikely to impact the Cusk population in these areas. The Cusk bycatch for 2012 in LFA 41 was estimated at 8.6 mt[1]. The 2006/2007 estimate of bycatch in LFA 34 was 344 mt. Cusk catches in other LFAs have not been evaluated.

Combined discards for 4X5Y groundfish longline, groundfish bottom trawl, and redfish bottom trawl fisheries were estimated to be 5.81 mt in 2011[2]. Specific estimates should not be construed as definitive or accepted uncritically as observer coverage for many fisheries is very low.

Currently, there is only one Food, Social, and Ceremonial (FSC) license that has a Cusk allocation for 2013/2014. No Cusk were harvested in 2011/2012 or 2012/2013 under this license. There were no reports of Cusk bycatch under any other FSC licenses. This may reflect a lack of reporting rather than an absence of any catch.

Cusk can be caught and retained by recreational fishers. No data were available to quantify this potential source of mortality. Catches are presumed low based on the depth preference of the species.

The mortality rate of discarded Cusk is thought to be high due to the high rate of barotrauma they suffer when brought to the surface. Symptoms include everted stomach, blistering, and damage to internal organs. Whether Cusk can survive barotrauma has not been studied. The

[1] Doug Pezzack, personal communication.
[2] Clark K.J., Hansen S.C., Gale J. Overview of discards from Canadian commercial groundfish fisheries in NAFO Division 4x5yb for 2007-2011 (unpublished manuscript).

practice of using Cusk as bait rather than returning them to the water will also contribute to mortality.

Threats were prioritized in a threats table prepared for the single population of Cusk, following the requirements laid out by DFO (DFO 2014b) (Table 2). The population-level threat risk (PTR) is calculated using rankings for severity and likelihood and plotting them in the Threat Risk Matrix (DFO 2014b) to derive an overall rank. The impact of commercial fisheries on the Cusk population is related to whether the fish are found in the area where the fishery occurs, the likelihood that the gear will capture Cusk, and the level of effort. In areas where there are little or no Cusk, the fishery will have no impact on the Cusk population. Groundfish longline and lobster pots are considered the greatest threats based on landings records and discard estimates, respectively (Table 2).

Table 2. Threats Table for Cusk. Categories were based on Cusk landings and discard information from 2002 to 2012. Column names represent: Likelihood (L), Severity (S), Causal certainty (CC), Population threat risk (PTR), Population-level threat occurrence (PTO), Population-level threat frequency (PTF) and Population-level threat extent (PTE).

Fishery	L	S	CC	PTR	PTO	PTF	PTE
Bottom Longline	Known	Medium	High	Medium	Current	Recurrent	Extensive
Lobster	Known	Low/ Medium	Medium	Low/ Medium	Current	Recurrent	Broad
Gillnet	Known	Low	Low	Low	Current	Recurrent	Restricted
Handline	Known	Low	Low	Low	Current	Recurrent	Restricted
Bottom Trawl	Known	Low	Low	Low	Current	Recurrent	Narrow
Scallop	Likely	Low	Low	Low	Current	Recurrent	Restricted
Shrimp	Likely	Low	Low	Low	Current	Recurrent	Restricted

Habitat

A species distribution model (SDM) of Cusk was used to understand the habitat preferences of Cusk, rank the most important environmental predictors of suitable Cusk habitat, and develop a prediction of suitable Cusk habitat to identify long-term important habitat areas. The species distribution model was applied as part of a national species at risk project, with the purpose of identifying tools, and creating a standardized geodatabase of environmental variables, to identify essential habitat for species at risk.

The most suitable habitat, in initial analyses, was predicted to be the outer German Bank area, the western Northeast Channel, Roseway Bank, the northern area above La Have Basin, and the slope of the Scotian Shelf (Figures 4 and 5). Roseway Bank and upper La Have Basin did not have landings as high as the other areas and could represent a depleted portion of the species niche. Another possibility is model error; the model could be over-predicting Cusk habitat. If over-prediction were the case, this could be due to poor sampling of over-predicted areas (as very few records are close to shore). In contrast, it could also be due to aggregation of the data from the various input data sources. In either case, planned updates to the model may reduce the predicted suitability of this area, but are not expected to affect the predicted suitability of the other areas.

Preliminary analyses also suggest that Cusk occurrences were predominantly in regions with specific oceanographic conditions. These variables are expected to have both indirect and direct relationships on Cusk distribution patterns. Indirect predictors are related to resources or

regulators and, therefore, correlate with species distributions, but they may be easier to measure than direct predictors. Examples are latitude, longitude, depth, slope angle and exposure. Ideally, variables describing direct and resource gradients would always be used in species distribution models. However, when only variables describing indirect gradients are available, it is important not to extrapolate the model results beyond the range of conditions used to develop the model. The six most influential environmental variables on Cusk habitat suitability, ranked using the Random Forest Model (Figure 6), were salinity variability, winter total suspended matter 2006-2010, fall benthic temperature, depth, root mean square (RMS) current stress, and winter benthic temperature. The order of environmental predictors should not be construed as definitive as updates to the model are planned

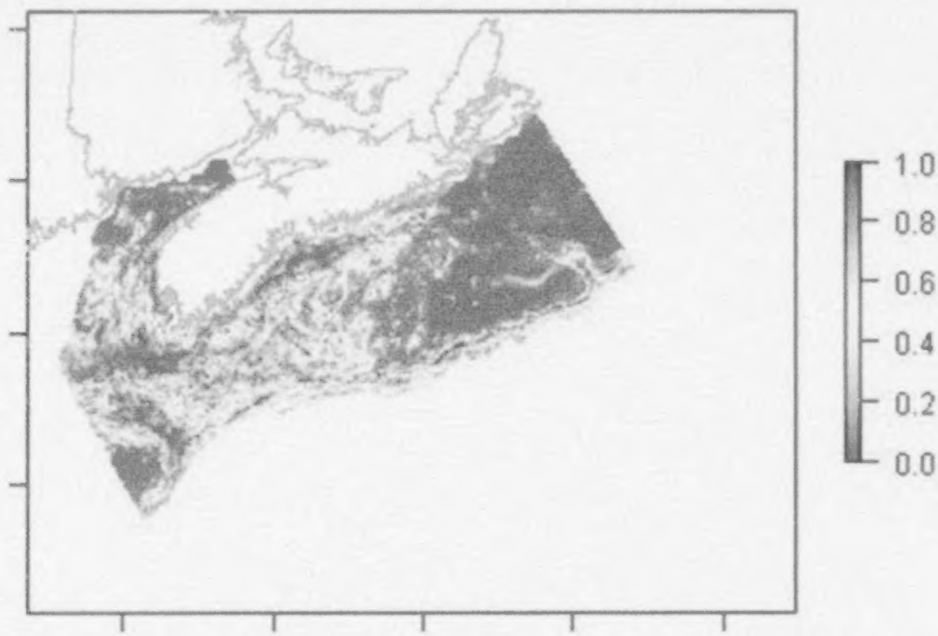

Figure 4. A map showing the predicted habitat suitability of Cusk over the Maritimes Region obtained by the application of the Random Forest model with colours scaled from a probability of 0% to 100%.

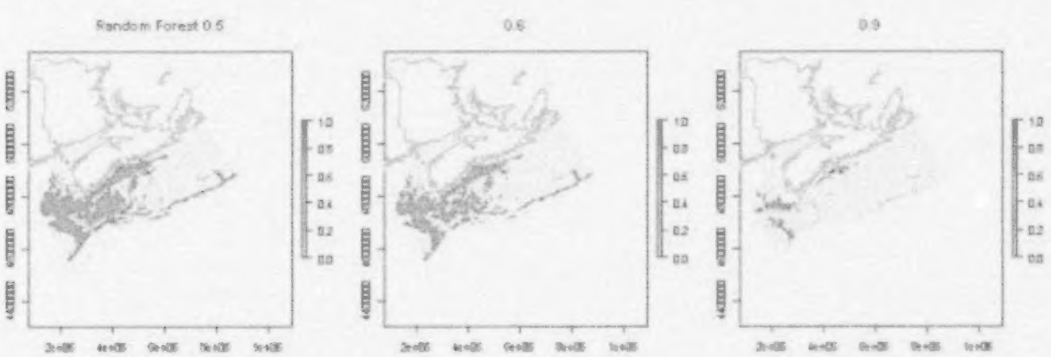

Figure 5. Maps showing the predicted habitat suitability of Cusk over the Maritimes Region obtained by the application of the Random Forest model with a threshold at 50% chance of presence, with a threshold at 60% chance of presence, and with a threshold at 90% chance of presence.

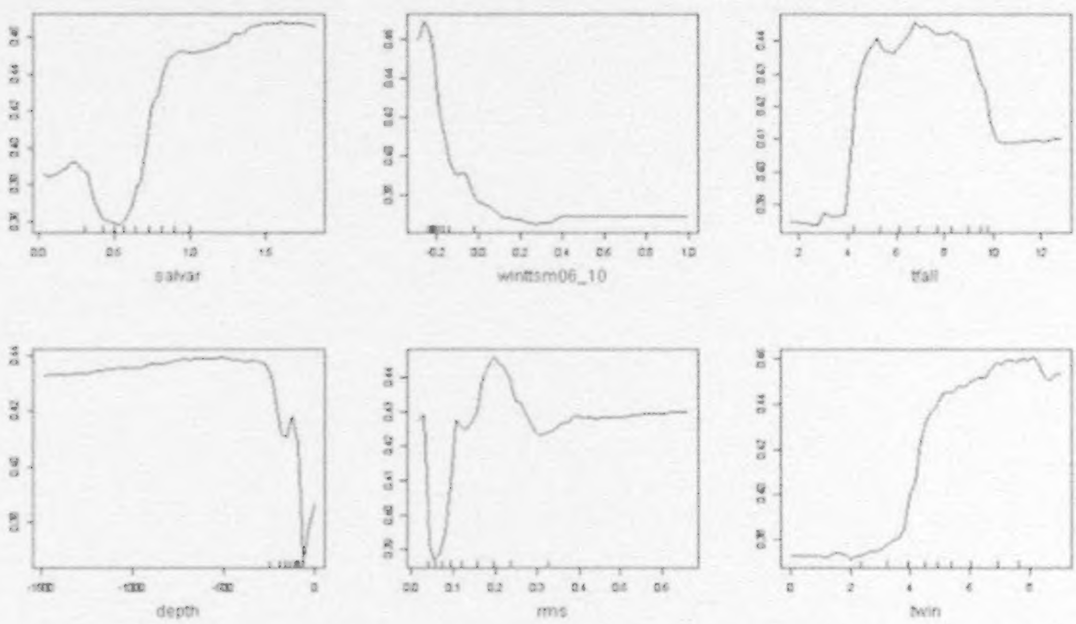

Figure 6. Partial plots representing the marginal effect of the 6 most important variables included in the Random Forest model on estimates of yield of Cusk while averaging the effect of all other variables. In a partial plot, marginal effects on the range of the values (and not the absolute values) can be compared between plots of different variables.

Initial analyses indicate that Cusk were more prevalent in areas with low total suspended matter (less than -0.05 log (g/m^3)). Cusk were less common in coastal areas with higher suspended matter, which corresponds to areas in the Bay of Fundy, and nearshore areas with higher tidal range.

Cusk were more prevalent in areas with a low (0.1-0.4 ppt) or high (0.6-1.3 ppt) annual range in benthic salinity, which is a bimodal response curve. Higher salinity ranges corresponded to the banks on the western Scotian Shelf. Cusk were less common in areas with a medium annual range in benthic salinity (approximately 0.5 ppt). This relationship is unlikely. For this reason, it is expected that mid-range salinities are an indicator of certain oceanographic conditions found within water masses associated with the Gulf of St. Lawrence outflow, and areas of greater tidal mixing and upwelling. These conditions could be related to a variable that physiologically influences Cusk or influences the distribution of their food sources. As described above, Cusk have a fairly generalized diet. DFO data from Canadian waters indicate that crustaceans, primarily decapods including various crab species and krill species; various fish species, including Silver Hake, Atlantic Herring, American Plaice, and Atlantic Argentine; and molluscs, primarily Short-Fin Squid, are the main components of Cusk diet. Polychaetes, echinoderms, and cnidarians made up a small proportion of the diet in this area.

Even though depth is an indirect predictor of habitat, initial analyses suggest that suitable Cusk habitat was within depths from 0 to 1500 m. Cusk were more prevalent between depths of 50 and 375 m, with highest occurrence at depths between 200 – 375 m. Cusk have been considered a deep-water species, although they are likely depth generalists, i.e., have a large depth-suitability range. The highest commercial CPUEs were between 50 and 375 m.

Based on the literature, Cusk are most common on hard, rocky bottom or gravel and have been observed hiding in crevices. Within specific oceanographic conditions (physiological constraints), benthic complexity was expected to be one of the most important predictors of

Cusk habitat. In the initial model, even though the relationship between Cusk presence and benthic complexity was significant, the benthic complexity index was not in the top ten environmental predictors. This likely reflects insufficient data on benthic complexity. Indeed, some regions with a low benthic complexity index (e.g. western Northeast Channel and Roseway Bank) are locations of frequent net damage in the DFO ecosystem survey, indicating complex rocky habitat.

Habitat does not appear to be, nor is likely to become, a limiting factor to Cusk survival or recovery. There are no known anthropogenic threats that have reduced Cusk habitat quantity or quality.

Future climate change and large-scale activities that would alter the seabed are the only potential threats to the functional properties of Cusk habitat. The effects of these potential threats are unknown and difficult to predict; however Hare et al. (2012) do predict that Cusk habitat in the Gulf of Maine and Scotian Shelf region will shrink and fragment. Their prediction is based on a spatial mismatch between high complexity seafloor habitat and suitable temperature conditions.

Cusk have a fairly generalized diet. It is not known how the development of a large-scale fishery directing for, or capturing any of their prey species as bycatch, may compromise Cusk's ability to feed. Given the variety of prey items, Cusk are likely less vulnerable than species with a more specialized diet.

Mitigation Measures and Alternatives

Fishing has been identified as the only known major source of anthropogenic mortality for Cusk. There are no known gear modifications or changes to bait type to reduce the catch of Cusk in any fishery. Efforts to decrease fishing mortality could include:

- Elimination of the retention of Cusk in commercial fisheries; however, given the expected high post-release mortality associated with catching Cusk, the impact of this measure on Cusk abundance is unknown.
- Elimination of the retention of Cusk in recreational or FSC fisheries; however, catches are thought to be low and the impact is unlikely to be significant.
- Closing areas of high Cusk abundance or areas where Cusk is the main species caught to groundfish longline fishing and/or lobster fishing. Figure 7 shows the areas associated with the 80th and 90th percentile of Cusk commercial longline landings. The amount of Cusk, Atlantic Cod, Haddock, and Atlantic Halibut caught in the 2012/2013 fishing year are in Tables 3 and 4, as is the ratio of Cusk to the other species.
- Implementation of an avoidance/move-away protocol as a condition of license in fisheries that catch Cusk (e.g. after catching some amount of Cusk/trip, must pull up gear and move a specified distance away).
- The development and implementation of Cusk handling and release protocols to maximize post-release survival.

Other potential measures associated with improved information and monitoring of Cusk could include:

- Increased at-sea observer coverage in the groundfish longline fishery in NAFO Divisions 4X5Y.
- Routine at-sea observer coverage in the lobster fishery.
- One-hundred percent dockside monitoring for the groundfish fixed gear fleet authorized to use vessels less than 45' in NAFO Division 4VsW and 4X5Y.

This is not considered to be an exhaustive list of possible mitigation measures. No alternatives to activities have been considered.

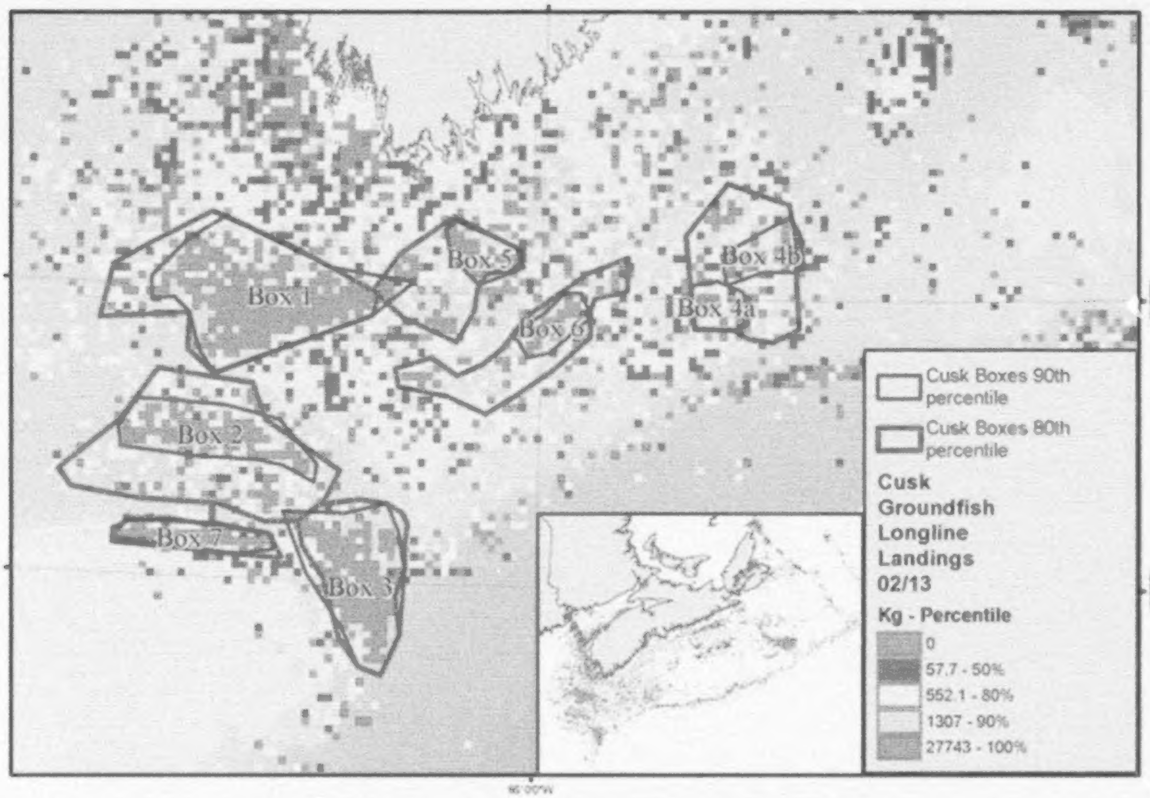

Figure 7. Polygons within the 80th (purple outline) and 90th (black outline) percentiles of Cusk catch weight from 2002 to 2013, and larger than 20 km in length/width, overlaid on the sum of catch weight in kg.

Table 3. A summary of Cusk, Atlantic Halibut, Atlantic Cod, and Haddock landings (kg) from 2012/2013 within 7 boxes of the 80th percentile of Cusk catch weight and larger than 20 km in length/width. The ratios of cusk landings to the landings of each fishery (Atlantic Halibut, Atlantic Cod, and Haddock) are also given. Ratios of the Cusk caught to the impact on each fishery can be used as a method of prioritizing the boxes. A higher ratio equals more Cusk saved and less impact to the fishery. The two highest ratios for each fishery are identified in bold.

Box	Cusk	Halibut	Cod	Haddock	Cusk/ Halibut	Cusk/ Cod	Cusk/ Haddock
1	**90,489**	**10,729**	**84,892**	**39,659**	**8.43**	**1.07**	**2.28**
2	10,887	4,476	24,007	230,492	2.43	0.45	0.05
3	**34,878**	**5,553**	**24,149**	**268,192**	**6.28**	**1.44**	**0.13**
4	10,980	24,833	27,208	107,423	0.44	0.40	0.10
5	21,923	48,722	59,072	25,050	0.44	0.37	0.88
6	10,901	55,730	42,618	59,142	0.20	0.26	0.18
7	9,716	4,296	112,688	349,028	2.26	0.09	0.03

Table 4. A summary of Cusk, Atlantic Halibut, Atlantic Cod, and Haddock landings (kg) from 2012/2013 within 7 boxes of the 90th percentiles of Cusk catch weight and larger than 20 km in length/width. The ratios of Cusk landings to the landings of each fishery (Atlantic Halibut, Atlantic Cod, and Haddock) are also given. Ratios of the Cusk caught to the impact on each fishery can be used as a method of prioritizing the boxes. A higher ratio equals more Cusk saved and less impact to fishery. The two highest ratios for each fishery are identified in bold.

Box	Cusk	Halibut	Cod	Haddock	Cusk/ Halibut	Cusk/ Cod	Cusk/ Haddock
1	87,184	12,496	79,595	37,772	**6.98**	**1.10**	**2.31**
2	7,889	2,993	17,483	51,074	2.64	0.45	0.15
3	35,247	5,908	25,780	217,590	**5.97**	**1.37**	0.16
4a	1,788	4,287	3,518	8,716	0.42	0.51	0.21
4b	1,486	5,205	3,978	14,506	0.29	0.37	0.10
5	9,306	22,266	20,537	5,687	0.42	0.45	**1.64**
6	6,177	19,777	17,674	9,593	0.31	0.35	0.64
7	11,515	4,437	120,185	255,542	2.59	0.10	0.05

Allowable Harm

No major potential sources of non-lethal harm to Cusk have been identified at this time and are not thought to be a concern. The only known major source of human-induced mortality is fishing mortality.

There are inadequate data to quantify the maximum human-induced mortality that Cusk can sustain and not jeopardize survival or recovery. It is believed that the stock can recover from human-induced mortality as it has been withstanding fishing pressure with no appreciable trend in recent years. The Halibut Industry Survey indicates that Cusk population status is in the cautious zone (Figure 3) and has been for 7 years. It appears that the population can sustain recent levels of fishing mortality without jeopardizing survival of the species considering Cusk CPUE in the Halibut Industry Survey has fluctuated without trend over the past 14 years. A further reduction in fishing mortality may be required for the species to achieve the proposed recovery target for abundance. It is not known if there are limiting factors (e.g. high natural mortality) that will prevent Cusk from recovering.

Sources of Uncertainty

Discarding of Cusk cannot be reliably quantified. Observer coverage is very low in many of the fisheries where Cusk are caught. It is also possible that discard rates differ on trips when no observer is present. The survival rate of discarded fish is unknown. Some released fish may survive, which would reduce the impact of a given fishery when discarding occurs.

There is a high level of uncertainty in the index from the Halibut Industry Survey index. The confidence interval often spans 2 or 3 stock status zones. In addition to the variability in catch rates, the implementation of the survey creates some uncertainty. Station coverage has been irregular. Of the 275 fixed station locations only approximately 50 have been consistently completed since 1999. The fixed station location can vary up to 3 nautical miles from station location, from one year to the next.

The area between Roseway Bank and Halifax and north of La Have Basin do not currently have landings as high as the other areas predicted as the most suitable habitat in the Random Forest model. Model updates have been suggested, which incorporate down sampling of the data instead of aggregation (this aggregation may account for the unexpected result). A realized niche model using the latitude and longitude of presence locations may also address this.

However the current model, a potential niche model, is useful as it suggests areas within the potential niche that Cusk do not inhabit, possibly due to a depleted population status. Abundance data could be used to analyze the variance in bycatch over time and determine if the niche has been depleted.

The depth data used to create the benthic complexity index are likely not adequate in some areas where Cusk are present.

Occasionally, overlapping time periods between the Cusk data and the environmental variable data could not be obtained and historical environmental variables had to be used. This was the case for many of the benthic modeled oceanographic variables (temperature and salinity). The assumption was made that historical modeled temperature and salinity would be predictive of current oceanographic patterns and conditions. This may not be the case as temperature patterns could have shifted or there could have been a warm or cold period during the time period. Current data could be interpolated or modeled using appropriate methods and made available to those who wish to model species distributions.

Research Recommendations

The survival rate of discarded fish is unknown. The mortality rate of discarded Cusk in the lobster fishery was estimated based on a visual assessment of fish condition. Experiments are required in order to get an estimate of mortality of Cusk in various conditions. Mortality rates will allow for the improved estimates of human-induced harm. It is also recommended that the effectiveness of recompression tools and techniques for Cusk be investigated.

The ageing of Cusk from sectioned otoliths should be completed in order to corroborate the bomb radiocarbon dating results.

Bait preference of Cusk should be examined as a possible mitigation measure in the lobster trap and groundfish longline fisheries. Catch rates of the target species should be taken into account in analyses and recommendations.

In an effort to better understand benthic complexity as a variable, attempts are being made to incorporate a variety of other multibeam data in to the depth and benthic complexity models. Development of an offshore substrate interpretation would also be an ideal product to investigate Cusk substrate preference.

There are significant knowledge gaps associated with life history, such as location and characteristics of spawning habitat, nursery areas.

The summer Research Vessel survey provides the longest fishery-independent index of abundance for Cusk, extending back to 1970. It has not been used in this or past RPAs because the index is thought to change more rapidly than population abundance (termed hyperdepletion). A population modelling approach that takes hyperdepletion of this index into account has recently been developed (Davies and Jonsen 2011). Population modelling using this approach should be investigated.

To quantitatively measure the population threat extent (the overlapping extent of the threat and the species at risk), a map of the extent of the various threats could be intersected with the "area of occupancy" or range of Cusk (e.g. the extent of the groundfish longline fishery). Intensity maps of the threats (kernel density plots of the fishing locations) and habitat suitability maps would also help understand the intensity of the threat in contrast to the most important long-term habitat areas for Cusk. These types of products could provide quantitative metrics to inform the threat assessment for species at risk.

Possible biological covariates could be examined as a proxy for Cusk distribution, given that there will be species co-occurring with Cusk that may be better sampled by DFO's fishery independent surveys.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 12-13, 2014, Update on Recovery Potential for Cusk (*Brosme brosme*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

COSEWIC. 2012. COSEWIC assessment and status report on the Cusk *Brosme brosme* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 85 pp.

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Centre for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
PO Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia
Canada B2Y 4A2

Telephone: 902-426-7070
Fax: 902-426-5435
E-Mail: XMARMRAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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